Space Weather Technical Forecast

Issued on Friday, 30 December 2022 at 13:16 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of G1/Minor Geomagnetic Storms mainly day 1 (30th), Chance of further M-flares throughout. Chance of Active High Energy Electron Fluence by day 3 (1st)

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate solar activity with one M-flare observed, peaking M2.4 at 29/1834 UTC from AR3180 Cso/Beta, a newly numbered region on the northeast limb. This is likely to reveal more complexity as it rotates onto the disc, and is also accompanied with a further small spot to the south, that may from part of the same complex. Other spots of interest include AR3176 Ehi/Beta-gamma, which is a large region in the northeast that has seen some reverse polarity spot development around its leader and AR3179 Dai/Beta, which is a smaller region in the northwest that has been developing fairly rapidly in the last 24 hours. AR3177 Csi/Beta in the southeast has also seen some development of small trailer spots. The other four regions, to give nine total on the disc, have remained small and simple. No Earth-directed CMEs have been observed.

Solar Wind / Geomagnetic Activity: Solar winds, as observed by ACE and DSCOVR were indicative of a turbulent transition into the fast wind, due to the arrival of the HSS of CH59/+. The preceding CIR, was potentially enhanced further by the glancing effect of a passing CME from the 25th. Initially slightly elevated speeds of around 420-450km/s, increased from 23/2100 UTC to be variable at 450-550 km/s. The density was generally around average, although DSCOVR was briefly above average 29/2230-29/2330 UTC. Total Interplanetary Magnetic Field (IMF), Bt, was initially weak (5-8 nT), before rising to Moderate briefly at 29/2200 UTC, and more persistently from 30/0100 UTC at 9-14 nT. The north-south component, Bz, was largely negative with brief oscillations into positive but with an increasing envelope of values. This initially varied between -6 nT and +4 nT, but between -11 nT and +12 nT by 30/1100 UTC. Phi angle was predominantly positive (towards the Sun) but with brief rotation to negative after 29/2200 UTC. Geomagnetic activity was Quiet to Unsettled at first, becoming Unsettled to Active from 29/2100 UTC with one G1/Minor Storm interval observed at 30/0000-0300 UTC.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at background levels. High energy electron flux (greater than 2MeV) as recorded at GOES16 was initially high, peaking 2730 pfu at 29/1550 UTC, before declining back to moderate, briefly background, levels. The 24-hour integrated electron fluence remained below the Active threshold. The observed fluence at 30/0000 UTC was 8.22e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is expected, with an ongoing daily chance of M-flares. There is a slight chance of X-class flares.

Solar Wind / Geomagnetic Activity: There are no Earth-directed CMEs, however ongoing fast wind influence from CH59/+, may also include some influence from a potential CME enhancement that was forecast to pass close to the Earth on the 29th. This left the Sun on the 25th. These fast winds are expected to persist day 1 and 2 (30th and 31st) with elevated winds

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of around 550-600 km/s only gradually subsiding to slightly elevated day 3 and 4 (1st and 2nd), and no further enhancement are expected. Geomagnetic activity is forecast to initially be Unsettled to Active, with a chance of G1/Minor Storm intervals, before gradually easing to be Quiet to Unsettled, with a chance of Active period by day 3 (1st) and mainly Quiet with isolated Unsettled intervals day 4 (2nd).

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux observed by GOES-16 is expected to remain at Background levels throughout but with a chance of rising alongside any notable flares, giving a very slight chance of exceeding the S1/Minor Storm threshold. High energy electron flux (greater than 2MeV) observed by GOES-16 is likely to be Moderate to Background at first, but with an increasing chance of reaching High levels as day two onward. The associated 24 hour fluence will then respond, likely exceeding the Active (1e8 integrated pfu) threshold day 3 and 4 (1st and 2nd), with a chance of rising above this level by the end of day 2 (31st).

Figure 1a. L1 Solar Winds

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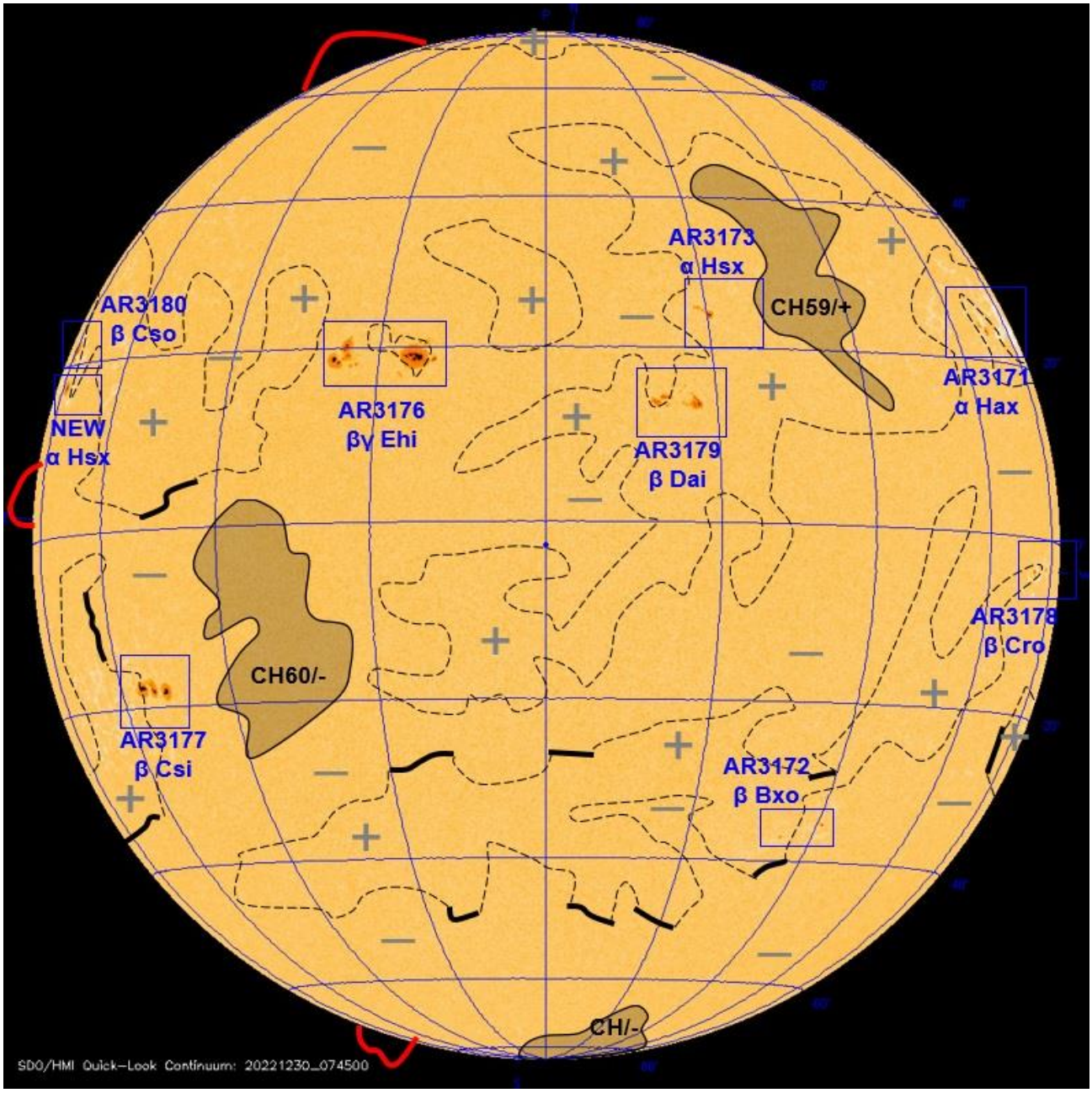
Figure 1b. Solar Analysis Valid 30/0800.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

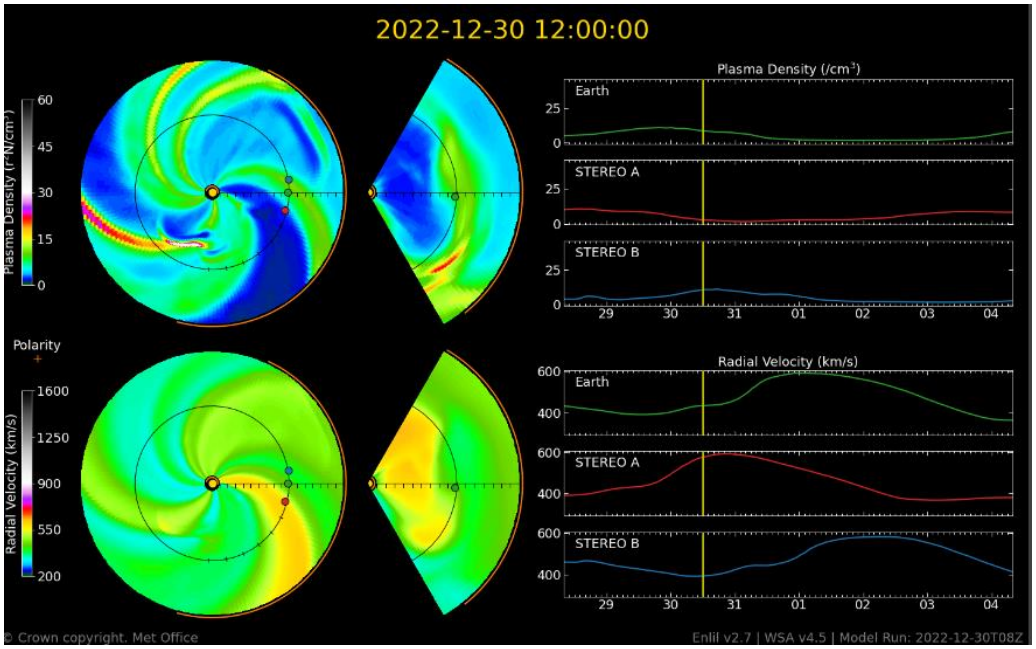
There are no Earth-directed CMEs expected to arrive during the forecast period. Current elevated solar winds are likely due to the transition into the fast wind, due to the arrival of a CIR region ahead of the high speed stream (HSS) of CH59/+. This was potentially enhanced by a glancing influence from a CME which left the Sun on the 25th, and was expected to pass ahead of the Earth on the 29th.

Ongoing fast wind influence is expected day 1 and 2 (30th and 31st), before gradually declining days 3 and 4 (1st and 2nd), with good confidence for MOSWOC enlil expectations. No further coronal hole enhancements are expected through the forecast period.

Initially Unsettled to Active geomagnetic activity, with a chance of G1/Minor Storm intervals, are expected to gradually ease to be Quiet to Unsettled, with a chance of Active period by day 3 (1st) and mainly Quiet with isolated Unsettled intervals day 4 (2nd).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	50	30	5	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Figure 2: Enlil solar winds. Despite late onset of elevated solar winds, showing these likely persisting through the period, only gradually easing 1st onward.



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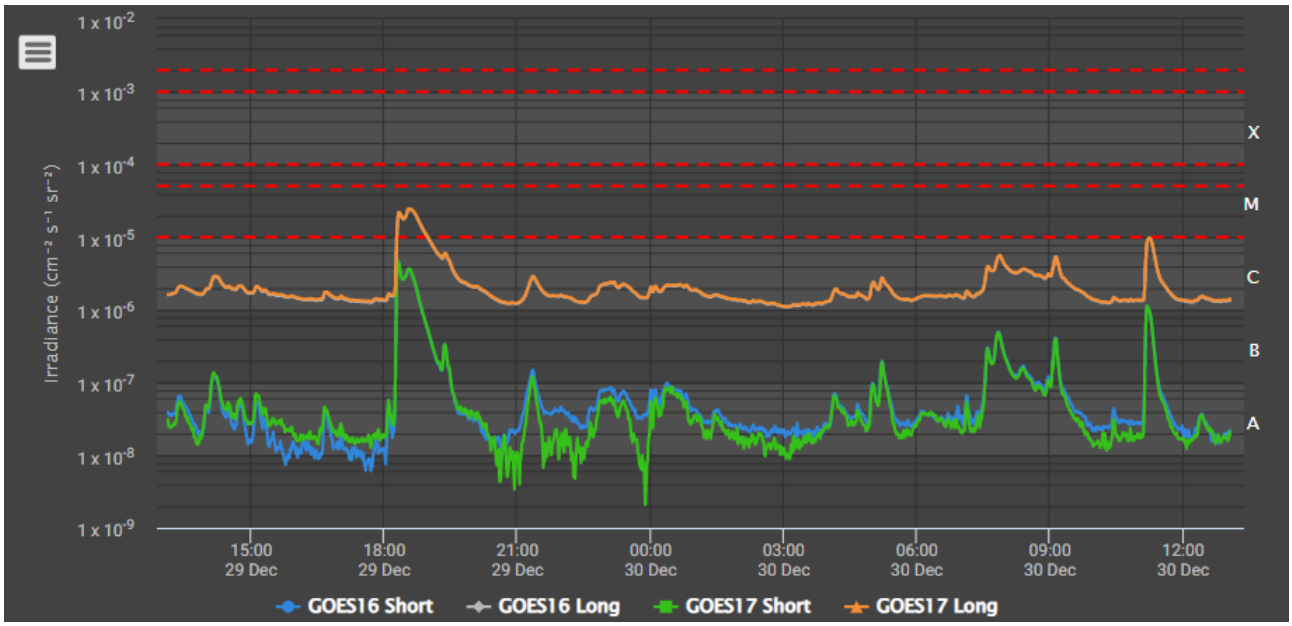
Radio Blackouts - X-Ray Flares:

Activity is expected to be Moderate to Low with an ongoing chance of M-flares and a very slight chance of X-flares. The most active region is currently a new Cso/Beta region rotating on the northeast limb, which was the source of the M-flares on the 29th. This remains difficult to analyse, with a nearby Hsx/alpha region potentially also forming part of a larger and more complex single region that will become easier to assess in the coming days.

Otherwise, AR3176 Ehi/Beta-gamma in the northeast is the largest region on the disc, with some small reverse polarity spot development around its leader resulting in a more complex configuration than its rather open east-west aligned configuration initially suggests. AR3179 Dai/Beta, in the northwest is also a relatively simple in terms of magnetic structure, but of note due to its relatively fast development in the last 24 hours. AR3177 Csi/Beta in the southwest is also of interest, with some development of smaller spots following what was initially a relatively simple but multi-spot unipolar region. Large sunspot AR3169 Fso/Beta has now rotated off the disc, whilst the other four regions on the disc (9 in total) remain smaller and simpler.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	55	55	50	40
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES 16-17 X-ray Flux



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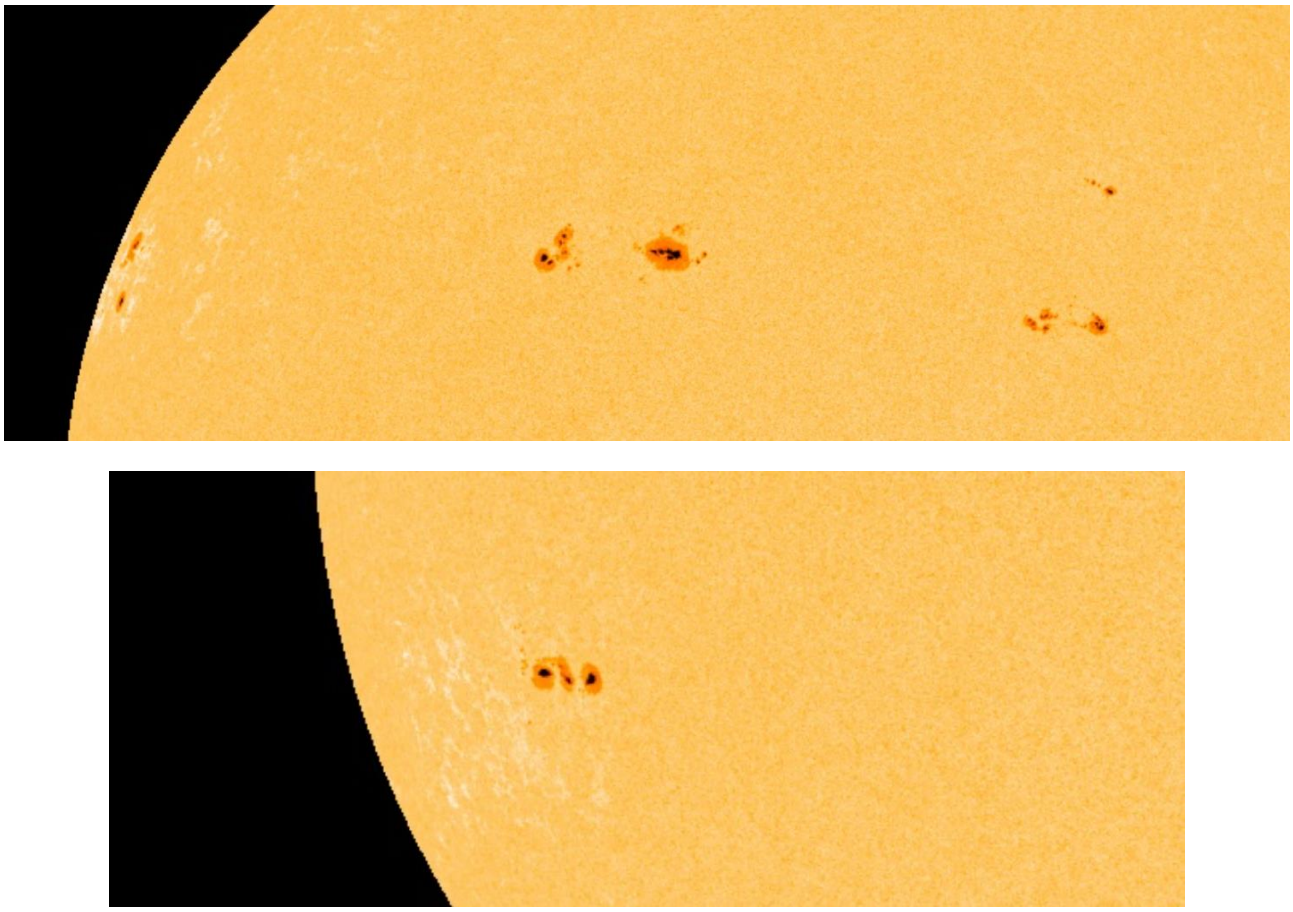
Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) measured by GOES-16 is at Background levels. Any significant will bring a risk of proton flux rising at points during the period, with a slight chance of exceeding the S1/Minor Storm threshold.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	5	5	5	5
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: SDO-hmi Intensitygram of sunspots on northern solar hemisphere (top) and the SE (bottom)



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High Energy Electrons Event (≥ 2MeV):

High energy (greater than 2 MeV) electron flux as observed by GOES-16 was suppressed by the onset of fast winds and potential CME influence over the previous 24 hours, and the subsequent compression of the Van Allen Belts inside of GEO. However flux is expected to rebound back to be Moderate to High (above 1000 pfu), by the end of day 2 (31st) or day 3 (1st), and perhaps becoming predominately High with no further suppression expected through the period.

The associated 24 hour fluence is expected to rise in response, approaching, and likely exceeding the Active (1e8 integrated pfu) threshold day 3 and 4 (1st and 2nd), with a chance of rising above this level by the end of day 2 (31st). REFM has yet to respond to the recent fast wind enhancement, so is currently giving poor guidance to expected fluence.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	40	60	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: GOES-16 >2MeV Electron Flux and associated 24 hr Fluence with REFM and Recurrence.

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